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Emergent Coordinators in the World Trade Center Disaster

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In this paper, we investigate coordination within responder radio communication networks during the World Trade Center disaster. We identify agents who are involved in high levels of coordinative activity, classifying their roles as institutionalized (i.e., mandated by formal position) or emergent. The extent to which coordination is effected by agents in institutionalized or emergent roles is then compared across networks of specialist and non-specialist responders. We find that, regardless of specialization, the great majority of coordinators occupy emergent roles. At the same time, where agents with institutionalized coordinative roles are present, they are substantially more likely to become actual coordinators. This uniformity across responder specialization suggests that event context may be as important as background factors in determining the emergence of coordination during times of crisis. As with past findings regarding improvisation in disasters, our results suggest obstacles for response policies that treat institutional status as an effective proxy for post-event role performance.

Key Words: Social networks, communication, organizational response, 9/11

Introduction

The importance of coordination during disasters has been documented by researchers and practitioners alike (Auf der Heide 1989; Drabek et al. 1981; Dynes 1970). In a context dominated by "many people trying to do quickly what they do not ordinarily do, in an environment with which they are not familiar" (Tierney 1985, p.77), achieving such coordination can be vital for effective disaster response. To this end, most emergency response organizations utilize institutionalized coordinative roles (e.g., dispatchers, desk

operators, liaison officers). Even within these organizations, however, conditions in the field may create coordination demands that cannot be satisfied via conventional procedures. Moreover, initial response activities are often conducted by persons who do not belong to emergency response organizations, but who become involved in the disaster response process due to their presence in the impact area. Where such circumstances arise, we may expect to observe the emergence of *ad hoc* coordinators from the responder population.

While the phenomenon of emergent coordination is well-known to disaster researchers (see, e.g., Drabek 2003; Dynes 1970; Stallings and Quarantelli 1985; Weller and Quarantelli 1973;), numerous important questions remain. For instance, the relative prevalence of individuals taking on coordinative roles (versus non-coordinative roles) during the immediate post-impact period is a question with significant implications for the design of responder information systems, as is the relative prevalence of institutionalized versus emergent coordinators. In addition, it is of both practical and theoretical interest to determine the extent to which these factors vary between emergency response organizations and organizations not normally tasked with such activities (e.g., building maintenance teams or transportation workers).

Here, we consider emergent coordination in the context of responder radio communications during the World Trade Center (WTC) disaster and outline some potential implications of our findings for emergency response planning. This analysis is especially relevant in the U.S. context, given present-day efforts within the federally mandated National Incident Management System (NIMS) to use a variant of the Incident Command System (ICS) as a comprehensive approach to disaster management. Although seen by many response practitioners as "the best way to create a universally applicable management model that satisfies response-generated demands created by disasters" (Buck et al. 2006, p.3), ICS has also been criticized because its unified command and control model fails to recognize a series of key factors in disaster response, particularly the transformations of the structure and function of established organizations during the response phase of disasters (Buck et al. 2006). To the extent that emergent coordination roles are prevalent within disaster settings, such weaknesses may be expected to pose a greater problem for emergency managers using a command and control approach.

The remainder of this paper begins by outlining prior results regarding communication and coordination during disasters, using these to motivate a series of hypotheses regarding coordination within the first hours of the WTC response. We examine the network structure of interpersonal communication during the event, identifying agents who are engaged in a high degree of coordinative activity. We then consider the extent to which such coordinators are institutionalized versus emergent (on the one hand), and the extent to which institutionalization *per se* is predictive of

coordinative activity (on the other). We also compare these relationships for organizations of different types to assess the impact of organization type on emergent coordination. As we shall see, these analyses point to a prominent role for emergent coordinators throughout the WTC emergency phase response.

Coordination in Disasters

Although defining disaster is a contentious issue, disasters have often been characterized as events in which social processes are substantially disrupted (Fritz 1961). Although they do not necessarily reduce the capacities of organizations or individuals to cope (Dynes 2003), disasters present them with new and often unexpected problems to solve. One of these problems is that of coordinating simultaneous efforts by a diverse population of agents. The response process typically involves joint interventions by multiple organizations focused on different problem domains (e.g., search and rescue, infrastructure deployment), as well as multiple agents within each organization carrying out a wide range of responsibilities (e.g., supervision, operations, accounting). In this context, coordination of activities is essential in order to avoid fragmentation, gaps in service delivery, and unnecessary duplication of service (Gillespie 1991) at both the interorganizational and at the interpersonal (intraorganizational) level.

Interorganizational coordination has been studied by many scholars both in disasters (e.g., Auf der Heide 1989; Drabek 1968; Roberts 1994; Topper and Carley 1999) and in more general settings (e.g., Baker and Faulkner 1993; Granovetter 1985; Powell 1990; Powell et al. 1996; Williamson 1975). Drabek and McEntire (2002) review research in the area, and find that, regardless of differences in views pertaining to the exact meaning of the term, the importance of multiorganizational coordination in disaster response operations has been consistently supported by field studies. If vital response activities such as search and rescue, medical care, traffic control, and resource allocation are carried out in an unstructured manner, the result can be insufficient resource allocation, omission of tasks, and even counterproductive activities (Auf der Heide 1989; Drabek 1968).

Compared to the wealth of studies on coordination among different organizations, intraorganizational coordination in disasters has been relatively understudied empirically; nevertheless, some useful theoretical frameworks have been articulated. Dynes's (1970) four-fold typology of organizational behavior during disasters usefully captures the changes (or lack thereof) in both structure and modes of task performance determined by disaster response. In Dynes's terminology, the *established organization* responds using its existing structure and routines. Typical examples of such organizations include police and fire departments, which are involved in emergency situations in the community on a regular basis. In the *expanding organization*, by contrast, established tasks are performed

by an increasing number of agents—the structure of the organization expands to incorporate these new members. In the case of the Red Cross, for instance, search and rescue activities are performed by volunteers who are mobilized to serve in response to a particular disaster (Drabek 1968; Dynes and Aguirre 1979). The *extending organization* employs its existing structures to meet the requirements of the disaster, while changing its routines and modes of task performance. This type is common among organizations whose involvement in an emergency response setting is unanticipated, such as firms that may be directly or indirectly impacted by disaster (see Wahle and Beatty 1990 for a practitioner-oriented view), or who volunteer their human and material resources for disaster relief (Dynes and Aguirre 1979). In the *emergent organization*, both the organizational structure and the modes of task performance employed in the response are substantially novel; these organizations have no predisaster existence and therefore no continuity or preexisting formal structure (Dynes 1970).

Given these distinctions, we expect that different types of organizations will have different coordination needs and strategies during disasters. For instance, since an established organization functions within old structures and responsibilities, it will tend to keep its coordination structure to a great extent and is expected to function according to existing plans (Dynes and Aguirre 1979). On the other hand, an extending organization will need new coordination mechanisms to accommodate its new routines and modes of task performance; thus, constant information exchange will be necessary for an adaptive response to the uncertainty of the environment.

Another factor that influences the process of coordination during disasters is the time frame in which the activities take place. Fisher's (1998) identification of five distinct periods in the life cycle of a disaster is especially useful in this regard. Following Fischer, the *pre-impact period* is one in which the persons who are likely to be affected by a predictable disaster (such as a hurricane) are informed about the imminence of the disaster and make preparations. The *impact period* is the most dangerous part of the disaster's life cycle and includes the actual devastating event. This is usually the shortest period, and a transition is made very quickly to the *immediate post-impact period*. This is the crucial interval in which survivors attempt to respond to ongoing hazards, search and rescue operations begin, and emergency response organizations deploy to the scene and attempt to coordinate their efforts. The first component of this interval—in which immediate response to hazards related to the disaster event is required to reduce further losses—is sometimes referred to as the *emergency phase*. During the *recovery period*, the community begins to reestablish the routines of daily life, with recovery/reconstruction of infrastructure and mitigation activities forming the *reconstruction period*.

The great majority of research on disaster response has been conducted relatively late into the immediate post-impact period or in the early recovery period (after the proverbial

dust has settled). This is due both to the difficulty of reaching and interviewing responders during and immediately after the initial impact, and to the time needed to assemble a research team itself. While understandable, such constraints leave us with a "gap" regarding emergency phase behavior. Given the critical role played by emergency phase actions in reducing losses to life and property (Auf der Heide 1989), this is not an inconsequential omission. The present study, in contrast, focuses directly on behavior during the emergency phase.[1] Thus, we now turn to consider some of what *is* known about emergency phase coordination.

The Context of Emergency Phase Coordination

In the emergency phase, uncertainty regarding both situation and response is high, and therefore rapid action is required to avoid further losses to lives and/or property. During this phase the immediate response is provided not only by trained responders, but also by other persons who happen to be present at the scene (Mileti et al. 1975). The demand for coordination escalates, and agents make use of both existing and emergent structures to find and provide help to peers, evacuate affected buildings, or provide basic security measures to prevent access to the impact area (Auf der Heide 1989; Drabek 1968; Galea and Blake 2004).

Specialist Versus Non-specialist Responders. Disaster response typically features actions by a collection of formal emergency response organizations whose missions are geared toward dealing with crises (Auf der Heide 1989). However, during the emergency phase the personnel of these organizations have not been completely mobilized and so in many cases the very first responders—the persons who immediately initiate actions such as giving first aid or coordinating evacuations—are not members of these organizations, but residents or transient bystanders (Mileti et al. 1975). Such responders may indeed conduct their activities within an organizational context (e.g., as when employees respond to a structure fire in a large firm), but are neither trained nor specifically equipped for such tasks. As a result, in the initial hours of the disaster response we have both trained responders and bystanders intervening to alleviate the effects of the disaster. In order to differentiate between these two groups, we refer to the former as "specialist responders", and to the latter as "non-specialist responders." To draw a parallel with Dynes' (1970) categorization, the "specialist responders" can be thought of as members of established organizations, which make use of their existing structure and tasks in disaster response, whereas "non-specialist responders" are more likely to belong to extending or emergent organizations, which are characterized by a new set of tasks and either old or new organizational structure.

Although their participation in disaster response is well documented by researchers, few studies focus specifically on specialist responders. Wenger et al. (1989) analyze police and fire departments in eight communities during a disaster, and note that even such organizations undergo structural changes in a disaster context, albeit on a small scale. For example, in the case of police departments, these changes can be observed in three critical areas: authority structure, decision-making processes, and the use of formal and informal communication systems.

The organizational authority structure within a disaster is altered by the fact that higher ranking officers tend to assume more authority than usual and, on the other hand, some officers in the field receive orders from non-police emergency officials. This modified authority structure can present problems consisting of "conflicting directives, a lack of coordination among the units, and the imposition of a non-traditional source of supervision over the individual officers" (Wenger et al. 1989, p. 29). As a consequence, decision-making is decentralized and may become indiscriminate, with officers being unable to grasp the whole picture and assigning inappropriate priority levels to various actions.

Communication plays a crucial role in everyday police work—dispatchers send and receive all radio communications with police officers on the road, handle telephone calls to and from the public and other agencies, and decide whether to send an officer to an incident and, if so, which officer (Kirmeyer 1988). During a disaster, however, the volume of communications increases dramatically and may overload the system, both in terms of the capacity of designated agents to handle the volume of calls, and of the capacity of the physical infrastructure to support the traffic (Drabek 1968). In these circumstances, agents that are not usually in charge of coordinating communication may take on such responsibilities in order to facilitate the flow of information. In a laboratory simulation of a police department during a disaster situation, Drabek and Haas (1969) found that sergeants (who normally are not central in handling cases) moved to the center of the team, receiving information from all sources and dispersing it among team members (p. 235). Thus, while specialist responders may be able to draw on resources designed for "routine emergencies," such resources may not be adequate to permit effective disaster response without additional adaptation.

In the case of a disaster, many organizations and individuals that are not normally mobilized in emergency operations may become involved because they happen to be present in the impact area. Studies of rescue activities in disasters show that this type of involvement is the rule rather than the exception (Mileti et al. 1975). Individuals who are in the immediate impact area and who have not been severely injured generally turn to help those around them (Dynes 1970; Tierney et al. 2001). In addition to activities by persons and organizations that happen to be in the immediate impact area, high-

consequence events may also motivate responses from entities that are proximate to the impact site. Such activities may include measures to ensure the safety of customers and employees, and/or attempts to aid those directly impacted by the event.

Although phenomena such as convergence of non-specialist responders to the impact site are fairly well-studied (Barton 1969; Fritz and Mathewson 1957; Kendra and Wachtendorf 2003c; Pangi 2002), little is known about the detailed structure of emergency phase interaction within such groups. Numerous studies suggest that non-specialists generally turn to coworkers, neighbors, or other nearby persons for information immediately upon learning of active hazards (Danzig et al. 1958; Drabek 2001; Richardson et al. 1979; Turner 1994), and will seek to secure safety for themselves and others nearby (Abe 1976; Mileti et al. 1975; Noji 1997; Quarantelli 1960), using familiar routes and resources where possible (Paulsen 1981; Smith et al. 1977). Following Forrest (1974), Drabek (1986) hypothesizes that growing groups of non-specialist responders will form an increasing number of formally designated positions, with increasing task specialization, enlarged administrative function, and increased number of hierarchical levels. If this is so, it would seem to imply that coordination demands will force initial, *ad hoc* response activities to give way to more systematically structured interactions. Where this process occurs within an organizational context, existing organizational structures may have to be repurposed and/or new ones may have to be created. What ultimately results, then, is likely to be an agglomeration of both emergent and planned behaviors.

Institutionalized Versus Emergent Coordination. In organizations, crises require the reworking of established and standardized procedures or the creation of new means and structures for carrying them out. Such structural adaptations may incorporate both novel uses of existing infrastructure and modifications to established social roles, depending on available resources and environmental constraints. In large part, the typical response pattern is a "mixed case," in which certain elements of routinized organizational behavior are combined with elements of emergent behavior (Dynes and Aguirre 1979, p.71). This is true of coordination as well as other organizational activities. To some extent, coordination may be performed by designated agents whose formal institutional roles mandate coordinative activity. While such institutionalized coordinators may be expected to play an important role (particularly in established and extending organizations), substantial changes arise from adaptation to the disaster environment, such as the assumption of coordinative responsibilities by agents whose duties typically lie elsewhere. Established ways of accessing information may become unavailable or deficient so new information seeking behavior may occur (Slagle Pipes and Knudson 2006). The capacity to make such adjustments involves creativity, and is a key element of organizational resilience (Kendra and Wachtendorf 2003b), as well as a factor in

organizational learning (Carley and Hill 2001). These emergent coordinators arise due to demands on the organizational structure that exceed the capabilities of conventional coordination mechanisms. As Kendra and Wachtendorf (2003a) note, "emergence is a significant coping response in times of crisis, augmenting the capacity of established organizations to meet shifting demands" (p. 125). By their nature, then, emergent coordinator roles are situationally contingent and may be expected to feature more strongly in some contexts than others.

Regardless of the type of organization and whether it is based on existing or emergent structures, coordination of activities within organizations, especially during the emergency phase, depends substantially on communication, particularly the collection and distribution of accurate information (Auf der Heide 1989). We now turn to the role of communication in coordination and the way the need for coordination may shape communication structures within organizations.

Communication and Coordination

The functioning of organizations depends upon the completion of a multitude of tasks. Tasks can be dependent on each other or on other elements for their completion, and resources and priorities need to be allocated so tasks are completed in the right order (Galbraith 1977). Since most organizations have different units in charge of particular aspects of task performance, coordination is necessary in order to prevent task interference (Perrow 1970). Dynes and Aguirre (1979) see coordination at the intraorganizational level as "the degree to which there are adequate linkages among organizational parts, i.e. among specific task performances as well as among sub-units of the organization, so that organizational objectives can be accomplished" (p. 71). Organizations can be coordinated through pre-established schedules and routines directing and standardizing the functioning of organizations (Dynes and Aguirre 1979; Galbraith 1977), but they depend as well on the transmission of information that facilitates adaptation to changes in the environment. In times of crisis, the need for new information that must be processed among decision makers during the performance of tasks grows proportionally with the uncertainty of the task (Galbraith 1977, p. 36).

As Drabek and McEntire (2002) have noted, there are various ways in which coordination occurs during disasters. In this paper, we restrict our attention to coordination as the process of relaying information so task interference is prevented and individuals' efforts can come together in a coherent response. The emergency phase response as a whole is highly dependent on communication, due to high levels of uncertainty and the need for coordination of time-sensitive response activities. Our attention to the communicative aspects of coordination should not be construed as

implying that other aspects (e.g., normative alignment) are unimportant. However, we regard the former as being especially important for activities during the emergency phase.

Communication Infrastructure

While emergency phase communication occurs via multiple conduits, one of the central technologies for responders in the field continues to be the two-way radio. Radio provides real-time voice communication for distributed units with minimal infrastructural requirements, a combination that is difficult to achieve with alternative technologies (e.g., telephony). Standard radio communication systems suffer from various well-known problems, ranging from the lack of common frequencies among response organizations to interference problems and "urban canyon" effects. Nevertheless, the ubiquity and versatility of radio communication makes it an important target for disaster research.

Although technical issues related to radio communication have attracted a great deal of attention (National Commission on Terrorist Attacks Upon the United States 2004), fundamental organizational issues are no less central to understanding the role of radio communication in response. Where communication breaks down, "people problems" can play as large a role as incompatible frequencies or interference (Auf der Heide 1989). For example, the so-called "Robinson Crusoe" syndrome ("we are alone on the island") emerges when individuals or organizations fail to factor in other individuals or organizations in conducting their activities. In such circumstances, agents may fail to exchange information with one another despite possessing the technical means to do so. Also problematic is a lack of consensus about who has responsibility for the collection and dissemination of various types of information, and over who should have access to it. Finally, agents who possess critical information may not be aware that others require it, and therefore do not pass it on. Such problems were apparent during the response to the World Trade Center disaster, as noted by the McKinsey and Company (2002a), which contains an analysis of NYPD response activities on that day. One of the issues was the lack of a "central point for collation and systematic analysis of information regarding [the] incident, with leaders acting largely on personal observations" (McKinsey and Company 2002a, p. 28). Moreover, the NYPD had "no clearing house for distilling, correcting and disseminating accurate information to responders" (McKinsey and Company 2002a, p. 28), which created a high level of uncertainty. Thus, communication during disasters depends less on the technical infrastructure than on the people using it.

Structural Signatures of Coordination

Where individual agents or infrastructural elements cannot be relied upon, organizational adaptation may be in the direction of decentralizing coordination activities that reduce dependence on particular units (Pfeffer 1978, pp. 20–21, 134–135). Loosely

coupled structures (Aldrich 1979; Weick 1976) may thus be expected to emerge as organizations restructure to minimize the effect of external perturbations. Consonant with the above, Dynes has argued that emergencies are characterized by decentralized and pluralistic decision making and, thus, that autonomy of decision making—rather than centralization of authority—should be encouraged (Dynes 2003, p.19). This structural shift tends to open up channels of communication that would normally be inhibited by status differentials. "The loss of status symbols, the shifting of personnel to new positions, and the influx of new personnel all contribute to a fluid status structure within the organization, and this accentuates the flow of information along the increased channel of communication" (Dynes 1970, p.176). Such changes, however, produce a new problem: how is coordination to be achieved in a decentralized environment?

Somewhat paradoxically in light of the recommendations of Dynes (2003), one structural signal of coordination, emphasized by the organizational literature, is centralization. Summarizing the results of his early work on the effects of structure in communication networks, Bavelas (1950) notes that "in patterns with a high, localized centrality, organization evolves more quickly, is more stable, and errors in performance are less" (p. 730).[2] By communicating with multiple alters, agents serving as "hubs" can consolidate information regarding events and activities, thereby reducing their alters' communicative load. Performance may be further increased, in many cases, by reducing redundant communication among non-hub agents; effectively, the task of information consolidation and allocation is delegated to the hub agents, freeing others to focus on alternative tasks. While such indirect communication may raise the concern of information loss due to relay error (Drabek 1985), it should be borne in mind that hub dominated networks can often allow for flexible message passing using few intermediaries. Furthermore, centralized structures are relatively well-buffered against the loss of non-hub members and the injection of inaccurate information by agents (Carley 1992).

We have presented so far two seemingly opposite views of how an intraorganizational communication network may be structured during a disaster. One line of reasoning suggests that decentralization is desirable because it opens up channels of communication hitherto closed due to status differentials (Dynes 2003). The second approach suggests that coordination (and, therefore, centralization) is vital for an efficient response (Auf der Heide 1989). The two views can be brought together, however, if we take into account the differences between global and local coordination. Decentralization, while necessary, does not automatically imply the total disappearance of coordinator roles, but instead the tendency for coordination to take place at a local, rather than global, level (by local, in this context, we mean subgroup level). The robustness of a communication network during a disaster may rest ultimately on its capacity to allow decentralization and the

emergence of local coordinators at the same time. Simulation results by Dodds et al. (2003) seem to confirm this intuition: they find that multiscale information exchange networks (networks that posses both local and global connectivity), show both congestion robustness (the capacity to protect individual nodes from congestion) and connectivity robustness—the capacity to remain connected even when individual failures do occur (p. 12519).

This interpretation, then, suggests that the emergence of strong coordinative roles will be reflected in the local centralization of the organizational communication structure, with highly central agents occupying the coordinative roles. In particular, we expect coordinators to possess two distinct structural characteristics. First, coordinators should have a large number of communication partners—by definition, coordinators must be involved in communications with multiple agents. Second, coordinators should *mediate* communications among their partners; that is, the fastest route for passing messages from one agent to another should typically be through a coordinator. In the language of network analysis (Wasserman and Faust 1994), coordinators can be said to be agents whose positions are high in both *degree* (number of partners) and *betweenness* (extent of mediation). As these quantities may be measured directly from the realized communication network, they may be employed to identify coordinators in practice. Further analyses may then be utilized to determine the extent to which empirically identified coordinators are institutionalized versus emergent in nature.

Predictions

Given the above, we proceed to examine several aspects of intraorganizational communication networks of specialist and non-specialist responders in the emergency phase of the World Trade Center disaster. We address two main issues related to coordination. First, we identify the coordinators (i.e., agents who have multiple communication partners and who mediate communication among alters), and determine whether their roles are institutionalized or emergent. Second, we compare the extent to which coordination is effected by agents in institutionalized or emergent roles across networks of specialist and non-specialist responders. Our hypotheses can be formulated as follows:

> H1: Specialist and non-specialist networks will exhibit wide divergence in basic structure (e.g., degree of centralization).

Although all responders studied here have radios and are thus familiar with the standard operating procedures of radio communication, the differences in mission, internal

organization, equipment, and expertise between responder groups leads us to expect substantial differences in communication patterns.

> H2: Agents whose formal roles entail coordination will be more likely to act as *de facto* coordinators than agents without such roles.

This follows from the assumption that responders will attempt to adhere to familiar patterns of communication during disasters (where possible), and that agents with formal responsibility for coordination are *a priori* more likely to be willing and able to perform such tasks.

> H3: A larger fraction of coordinators will be institutionalized in specialist networks than in non-specialist networks.

As mentioned above, specialist responder organizations can be viewed as established organizations, which rely on existing structures and personnel during disaster response. As such, coordinator roles are likely to be performed by agents whose job description includes coordination duties. Fewer agents with such status are expected to occur in non-specialist networks, leading to a corresponding reliance on emergent coordinators.

> H4: Institutionalized status will be a better predictor of coordinative role-taking in the specialist networks than in the non-specialist networks.

As established organizations, responders in specialist networks are expected to preferentially defer to those whose formal position entails coordination. In extending and emergent organizations, by contrast, the renegotiation of roles and procedures is expected to lead to a more flexible organizational structure which is less well-determined by pre-impact forms. This should lead to a reduced impact of institutional status on coordination behavior.

As a side note, it should be emphasized here that we do not extend our inquiry into organizational performance and efficiency per se. Although an important aspect of disaster response evaluation, this type of analysis was not possible due to the limitations of the available data. Neither was it possible to obtain baseline communication structures for these groups from the pre-impact period. As such, we cannot measure the extent to which the observed structures deviated from typical, baseline behavior. That said, the nature of the event (as documented by the 9/11 Commission Report 2004) and the qualitative content of the observed communications (see below) strongly argue against a "business as usual" hypothesis. Since our predictions relate to coordination during the

emergency phase itself (rather than to changes per se), this is not a critical limitation; a baseline comparison would, however, aid in interpretation.

Method

On the morning of September 11, 2001, two hijacked airplanes crashed into the WTC, leading to large structural fires and the subsequent collapse of the North and South Towers (30 minutes apart). This event triggered the largest response operation in the history of New York City, ultimately involving hundreds of organizations (Tierney 2003a). The agencies that were called immediately to the scene and that were most heavily involved throughout the emergency phase were the Fire Department of New York, the New York Police Department, the Port Authority Police Department, and the Office of Emergency Management and Interagency Preparedness (National Commission on Terrorist Attacks Upon the United States 2004). Although there are several sources of information about the interventions undertaken by these agencies (National Commission on Terrorist Attacks Upon the United States 2004; McKinsey and Company 2002a; 2002b), the most detailed data available concerns the Port Authority of New York and New Jersey (PA). As a result of a lawsuit filed by the New York Times in 2003, the PA released a set of documents pertaining to the events of September 11, 2001. The complete set contains reports of PA police officers and transcripts of radio and telephone conversations between PA employees (both police officers and other personnel) conducting activities inside the WTC and the PA command centers at airports and other facilities.

The data employed in this study consists of a set of PA transcripts containing radio communications among responders to the WTC disaster, each transcript representing all conversations on a single radio channel for a specified period. There are 19 transcripts in all, but two of them cover the same channels (in poorer quality versions), and thus the total number of transcripts we analyze is 17. Their length ranges from 7 to 80 pages (median, $Md = 43$, Interquartile range, $IQR = 35$). All transcripts begin immediately after the first airplane crashed into the North Tower at 8:46 am, and their length depends on the channel used and the location of the communicants (communication on certain channels being terminated by the collapse of one or both towers). The transcripts of conversations between employees located within the WTC itself are roughly 1 hour and 15 minutes in length, while all the others are 3 hours and 33 minutes long. Because each channel appears to have been used exclusively by a particular group of actors (with little or no "channel-hopping"), we treat each as synonymous with the organization employing it. While this would not be a reasonable assumption in the case of organizations such as

the FDNY (McKinsey and Company 2002b), it accurately reflects the content of the PA transcripts (see also National Commission on Terrorist Attacks upon the United States 2004, p. 281).

It should be noted here that transcription of the original recordings was performed at the PA's discretion and we do not have detailed information regarding this process. Where possible, we have performed internal checks to verify the accuracy of the transcription process using other available documentation. Our verifications suggest that the transcription is consistent and that the transcripts are accurate representations of the original conversations. Nonetheless, it should be borne in mind that conclusions reached in this study are necessarily conditioned upon the accuracy of the initial transcription.

Transcript Coding and Network Extraction

Each of the transcripts contains a list of statements exchanged between responders, presented in the chronological order of their transmission. The transcriber also provides a name tag for the sender, at the beginning of each statement. Based on the information available, this name tag includes some or all of the following: gender, name, rank, and organization. The information included in the name tags was combined with other content and contextual information to code the identity of the sender for each transmission. The identity of the receiver was similarly inferred from information contained in the statement (either a name or an indication that the statement was part of an ongoing conversation for which the participants had already been identified).

The task of identifying senders and receivers proved to be nontrivial in certain cases. Although the transcriber provides some information regarding the identity of the sender, there are two problems that make the identification difficult. First, transcribers do not provide the same amount of information across transcripts—some state only the gender of the sender, whereas others give additional information such as an indication of the organization with which the sender is affiliated. Most transcribers additionally split the transcript into segments of conversation, uniquely identifying senders within each segment. However, this was not performed in all cases. Second, the original recordings appear to have been garbled in some places, indicated by the transcriber via "inaudible" tags. Where transmission content is marked inaudible, identifying information is sometimes lost. Given these constraints, sender/receiver coding was accomplished using a combination of transcriber-supplied information, communicants' use of names and call signs, sequence information, and conversational cues. If a communication was directed to two or more recipients at the same time, it was coded as several dyadic communications from the sender to each of the named recipients. However, because we do not have complete rosters for the organizations involved, broadcasts, i.e., communications where the recipients were named as a group ("all units", "all mechanical personnel") were not

included in the list of coded communications. The resulting list of discrete communications by sender and receiver was then employed to construct the aggregate communication network for each transcript.

Due to the size and complexity of the dataset, multiple coding of the entire sample was infeasible. However, reliability of the coding process was assessed by systematically comparing the initial codes to codes generated by a second coder on a random sample of transcript excerpts. Our procedure was as follows. A random sample of 50 transmissions was first drawn from the entire dataset (i.e., all transmissions aggregated across all transcripts, for a total of 15830 transmissions). For each of these transmissions, the next transmission within the same transcript was then selected, forming 50 sequences of two transmissions. Each sequence was then coded by a second individual trained in generic coding rules, but ignorant of the initial coding and without prior experience with the materials. This coder was asked to make four judgments regarding each sequence:

- whether the sender of transmission 1 was the sender of transmission 2
- whether the sender of transmission 1 was the receiver of transmission 2
- whether the receiver of transmission 1 was the sender of transmission 2
- whether the receiver of transmission 1 was the receiver of transmission 2

This resulted in 200 judgments, which were then compared with the initial coding. The overall agreement between the initial and the secondary coding was 95 per cent (190 times out of 200 the two coders were in agreement). Furthermore, in 82 per cent of cases (41 out of 50 sequences) the two coders agreed on all four judgments (i.e., complete agreement). From this we conclude that the reliability of the coding process is sufficiently high to justify the use of the data obtained through the initial coding.

Once each discrete communication was coded for sender and intended recipient(s), a communication network was extracted from the data for each transcript. Each network in question is a directed multigraph (Wasserman and Faust 1994) on the set of named communicants, where each (i,j) edge represents a distinct communication in which actor j was a designated recipient of a message from actor i. For purposes of the present research, this multigraph was further simplified into a digraph in which an (i,j) edge exists if and only if there exists at least one (i,j) edge in the corresponding multigraph; this threshold was chosen because it marks the qualitative distinction between the existence of some communication and no communication at all. Except as noted otherwise, all analyses shown here refer to these directed graphs.

Coding for Specialist Versus Non-specialist Status

The PA manages a series of facilities that include the LaGuardia, John F. Kennedy and Newark Liberty airports, the Holland and Lincoln tunnels, and the Port Authority Trans-Hudson (PATH) train system. The PA has its own police department, whose officers are trained in fire suppression methods as well as in law enforcement. There is a separate command for each of the PA's facilities, including the WTC. The PATH operated a train station directly underneath the WTC complex and Newark Airport was the departure airport for one of the hijacked airplanes. All units described here were thus involved in the initial response to the attacks.

In this data set there are nine communication networks of "specialist responders," people who are trained and equipped to respond to crisis situations as part of their standard duties. They include the Lincoln Tunnel Police, Newark Airport Police, PATH police, WTC police and security as well as the New Jersey State Police Emergency Network (SPEN). In addition to these specialist responder networks we have eight communication networks of "non-specialist responders," people who lacked special equipment and training but who, nonetheless, participated in the disaster response because they were present at the scene. The very first rescue and evacuation activities were initiated and performed to a great extent by civilians who worked in the WTC, as well as by PA civilian employees. As the 9/11 Commission Report puts it, "the first response came from private firms and individuals—the people and companies in the building. Everything that would happen to them during the next few minutes would turn on their circumstances and their preparedness, assisted by building personnel on-site" (National Commission on Terrorist Attacks Upon the United States 2004, p. 286). Detailed information on the coordination involved in carrying out such improvised response activities is rarely available when studying disasters. Our data, however, includes communications among WTC building employees in the mechanical/electric, operations, and vertical transportation units, as well as employees of the PATH train system and Newark Liberty Airport during the first hours of the disaster. The PA data is thus unique in providing a glimpse of the manner in which both specialist and non-specialist responders deal with extreme changes to their environment.

Coding for Institutionalized Coordinator Role

To assess the extent to which formal status does or does not impact coordination, it was necessary to identify individuals whose formal roles entailed coordination. As this was not directly available, such status was inferred from the content of the available transcripts. We coded vertices as having institutionalized coordinator roles if their labels (or terms of address) contained one of the following words: "command," "desk,"

"operator," "dispatch(er)," "manager" (for the non-specialist networks), "control," or "base." In two of the Newark Airport transcripts, the content of the communications suggested that actors were referring to a central Newark Airport command desk as simply "Newark Airport," so the vertex with that label was also assigned institutionalized status.

Results

We begin our presentation of results by briefly summarizing the content of each of the transcripts to give the reader a glimpse of the activities undertaken by the responders and the presence of coordination. To this end, we also provide quotes that exemplify some of the most common situations with which the actors were confronted. We then proceed to the main body of the analysis, starting with an examination of the main structural features of the networks and continuing with the identification of coordinators and the nature of their role. Both these issues are comparatively examined in specialist and non-specialist networks.

Coordination at the WTC

In many disaster studies, information is collected after the most urgent part of the response operations has passed, with informants relying on recollections to reconstitute their activities. By contrast, the type of data we have available provides us with a direct account of the activities of the actors during the observation period. To our knowledge, this is the first study for which such data has been available and employed to study the detailed patterns of communication among responders in the first hours of a disaster. The primary activities covered by each transcript are described in Table 1.

In addition to these general descriptions, the content of the transcripts provides a great deal of insight into the nature of the coordination tasks being performed by the WTC responders. For instance, coordination for many non-specialist groups at the WTC complex centered on locating colleagues and negotiating an assembly area at which personnel were to gather after exiting the complex. A typical exchange of this sort is represented by the following excerpt from the WTC operations transcript:

> MALE: John, I'm on Church Street right in front of Century 21. Get everybody over here! (Inaudible) everybody, meet me on Church and Liberty, right on the corner.
> MALE: Copy that. That's Church and Liberty.
> MALE: Two-two to all two-nine ABM, meet me on the corner of Church and Liberty.
> (wtc.operations)

Table 1: Summary of Primary Activities Covered by Each Transcript

Responder type	Channel name	Transcript summary
Specialist	lincoln.tunnel.police	The Lincoln Tunnel Police Department coordinates traffic through Lincoln Tunnel and cooperates with other police units to give them access to New York City.
	newark.command	Mobilization of police and fire units and equipment to be deployed at the WTC. This channel is also used by personnel who are making sure that no unauthorized persons enter Newark Airport (which is closed at that time).
	newark.police	Newark Airport command communicates with police units deployed at the WTC.
	newark.CPD	Newark Command Post tries to communicate with the command post vehicle in the field and assess the general status of emergency response activities.
	njspen1	The State Police Emergency Network is used by New Jersey State Police units to coordinate their efforts and gather resources from all locations, as well as to regulate access into NYC via bridges and tunnels.
	njspen2	The PA Command Post communicates with police units inside WTC on State Police Emergency Network 2. After the South Tower collapses, they are trying to evacuate the North Tower.
	path.police	Communications between the PA Police Department (PAPD) central desk and the PAPD PATH desk, and PAPD officers deployed at the WTC.
	wtc.police	PAPD officers coordinate the evacuation of WTC buildings.
	wtc.security	Security personnel organize the rescue of civilians trapped in different parts of the North Tower.
Non-specialist	newark.operations.terminals	Newark Airport is closed, so the main desk coordinates personnel to take care of stranded passengers, luggage, and airplanes, and to evacuate terminals.
	newark.maintenance	Maintenance personnel communicate among themselves, trying to determine what has happened at the WTC.
	newark.facility.management	Newark Airport personnel communicate while taking the necessary steps to close down the airport.
	path.control.desk	Due to the attacks, service at the WTC PATH station is interrupted, and the control desk coordinates train traffic in the rest of the system.
	path.radio.communications	Communications among PATH personnel, who attempt to locate one another and account for their colleagues.
	wtc.operations	Operations personnel from WTC self-evacuate and reassemble in a different location on one of the nearby streets.
	wtc.vertical.transportation	Vertical transportation personnel self-evacuate and regroup at a different location.
	wtc.maintenance.electric	WTC electric and mechanical personnel coordinate to self-evacuate and regroup at a different location.

Note that this coordination process includes both selection of an appropriate assembly area and communication of this information to others in the group. This task was made difficult by the frequent need to relocate due to falling debris or other hazards, as well as the more mundane need to find a location that was identifiable by all group members.

> FEMALE - JERRY: Two-two to two-two John.
> MALE - JOHN: Go ahead, Jerry.
> FEMALE - JERRY: (SIRENS IN BACKGROUND) They're chasing us from this corner. I'm going to move (Inaudible).
> MALE - JOHN: Jerry, why don't we meet at 125 Broadway, in that big square?
> FEMALE - JERRY: Okay.
> (wtc.operations)

Since this information was not held by all group members in common, it was frequently necessary for some communicants to inform others regarding new circumstances (e.g., the need to relocate due to shifting police lines). This, in turn, would initiate a new round of site selection, with this result also relayed to group members.

> MALE - JOHN: Frank, go over and meet Jerry on 125 Broadway, on the side block. Frank, you copy that?
> FRANK: (Inaudible) one, John. I got Jerry, uh, we're over by the cube. We're trying to go out Borders.
> MALE - JOHN: We'll make that the meeting ground.
> (wtc.operations)

The central importance of spatial information for coordination of activities was not limited to non-specialists. Communication among responders frequently involved exchange of present location, as in this example from the WTC police transcript:

> MALE: Eight to, uh, eight-one.
> MALE: This is eight-one.
> MALE: Beginning evacuation of the entire complex, all buildings, copy?
> MALE: Roger, eight. Roger, eight. What's your location?
> MALE: I'm on Liberty Street (Inaudible), copy?
> MALE: Roger, I copy.
> (wtc.police)

As can be seen, one unit (eight) here signals to another (eight-one) that he is initiating evacuation of the WTC complex. By relaying this information to other units, eight-one could prevent them from attempting to do the same operation or other operations that might interfere with it. As a secondary aspect of the interaction, however, eight-one requests spatial information regarding eight, which is reciprocated. This information, in turn, might be used to answer queries from other agents in the event that the communicants can no longer reach each other directly. These minor, secondary exchanges thus play a critical role in facilitating the constant diffusion of status information throughout the communication network, without a centralized mechanism for position-keeping.

As one might expect, we also see exchanges of orders and directives via the communication network. A typical example comes from the Lincoln Tunnel Police transcript:

> MALE CENTRAL: Okay, Lincoln Tunnel, Central, (Inaudible) watch, all river crossings to New York are to be shut down. No traffic going into New York. Copy? No traffic going into New York.
> MALE LINCOLN TUNNEL: Roger. (25:51) (Inaudible) 8-2 do you copy? No traffic going into New York.
> (lincoln.tunnel.police)

Note that the responder identified as "Lincoln Tunnel" plays a coordinating role, here, by calling to a third party (8-2) and verifying that he or she has received the order. Since relaying the information is in principle unnecessary (if 8-2 is monitoring this channel, he or she should have heard the directive), the coordinative activity lies in verifying that the information was received and understood. By taking on this task, Lincoln Tunnel frees Central to pursue other activities; this is hence a simple case of the communicative load-shifting described earlier.

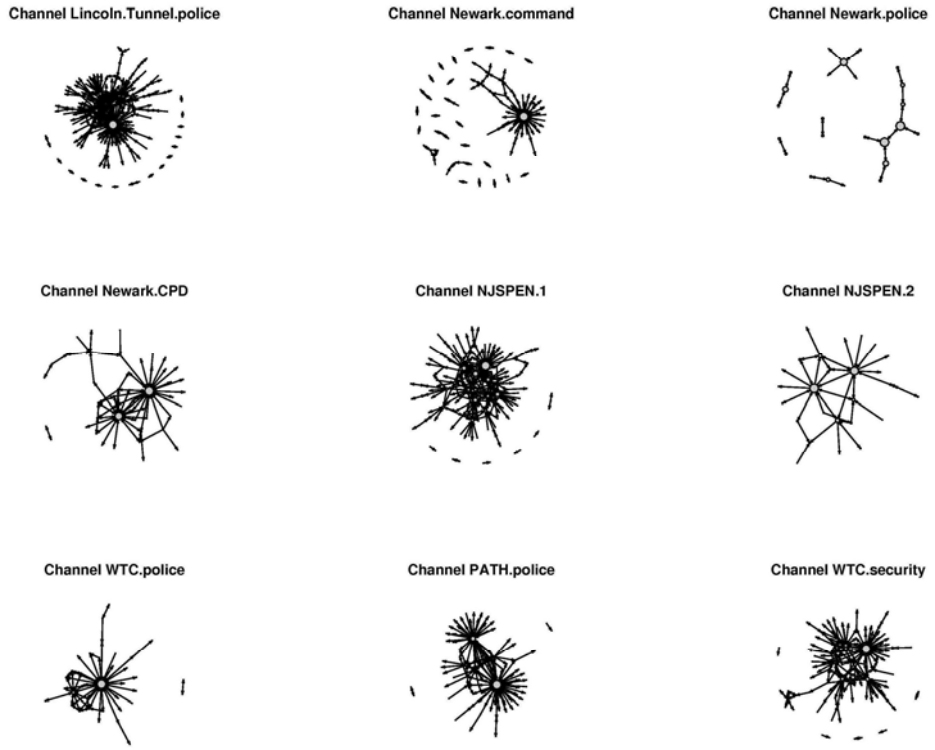
As the above suggests, the tasks attempted by the responders—specialist and non-specialist alike—involved great amounts of coordination. The constant need for information about the location of peers and safe places to reassemble, measures taken to secure the area, and orders from other units leads to patterned communication among responders (and hence, communication networks). It is to these networks and their properties that we now turn.

Local Centralization and Coordination

We begin our analysis of the WTC radio communication networks by a visual inspection of the sociograms (network diagrams) for each channel. Figures 1 and 2 depict the networks for specialist and non-specialist responders, respectively. Individual responders within each network are represented by circles (*vertices*), while ties between responders are represented by arrows (*edges*). To highlight potential coordinators, vertex sizes have been scaled by the corresponding individual's total number of communication partners, that is, the total degree (Wasserman and Faust 1994).

As Figures 1 and 2 clearly show, coordinators play a substantial role in mediating communication for all WTC channels. In each case, a small number of high-degree vertices act to connect a large number of agents who do not otherwise communicate with one another. The result is a collection of highly structured networks, in which coordination tasks appear to have been concentrated into a relatively small number of hands. This is clearly the case for both specialist and nonspecialist responder networks, suggesting that this concentration is not a property of specialization alone. Indeed, comparison of the two sets on a standard measure of concentration (degree centralization) does not reveal a significant absolute difference in mean centralization scores ($p = 0.094$, two-tailed permutation test). Repeating the analysis as a one-tailed test of differences—a much more liberal criterion—does yield a marginally significant tendency for specialists to be more centralized ($p = 0.047$), although this does not retain significance when medians are used in place of means ($p = 0.054$). Given the non-robustness of this result, and the failure to achieve significance under a two-tailed test, we conclude that any between-group differences in degree centralization are minimal at best. It would seem, then, that the domination of responder communication networks by a relatively small number of agents with many communication partners should be viewed as a common property of networks in the WTC disaster, rather than a phenomenon restricted to networks formed by professional responders. More broadly, it is immediately apparent that hypothesis H1 (which postulates *substantial* divergence between group structures) is unsupported. While there is some suggestion of more subtle differences between specialist and non-specialist networks, (a question which is pursued in detail elsewhere (Butts et al. 2007), we do not see any evidence of gross structural differences between these groups.

Figure 1: Sociograms for WTC Radio Communications, Specialist Responders

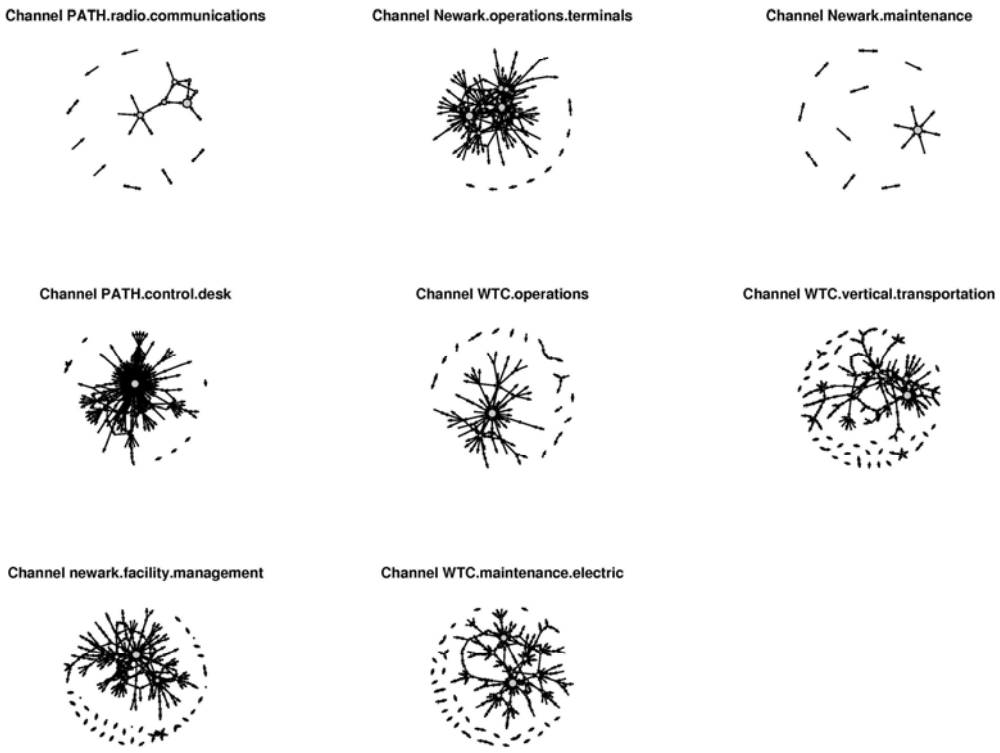


The Incidence of Coordinative Roles

While the sociograms of Figures 1 and 2 confirm that prominent coordinators are present within each communication network, they provide little insight as to the nature of the agents who occupy those positions. Similarly, it is difficult to ascertain from sociograms alone the extent of the relationship between the two necessary elements of coordination: *direct* communication with many alters, and *mediation* of communication among alters with limited alternative means of contacting one another. The first of these elements corresponds to the network property known as *degree*, i.e., the number of alters to which a given ego is tied.[3] The second of these elements can be assessed in several ways, but the most common is via a structural property known as *betweenness* (Wasserman and Faust 1994). As the name implies, the betweenness of a given ego is a measure of the extent to which ego lies on the shortest paths between many pairs of alters. A responder in a high-betweenness position, then, is likely to serve as a critical linch-pin in any attempt at rapid message-passing among disparate groups of responders. Although betweenness and degree are often correlated, they are distinct concept. A responder embedded in a large, tightly connected team might have high degree and low

betweenness, whereas a responder serving as the sole bridge between two otherwise disconnected teams might have high betweenness and low degree. (See also Freeman, 1979) for a more wide-ranging discussion.) It is the conjunction of these two formal properties, then, that defines a coordinative position.

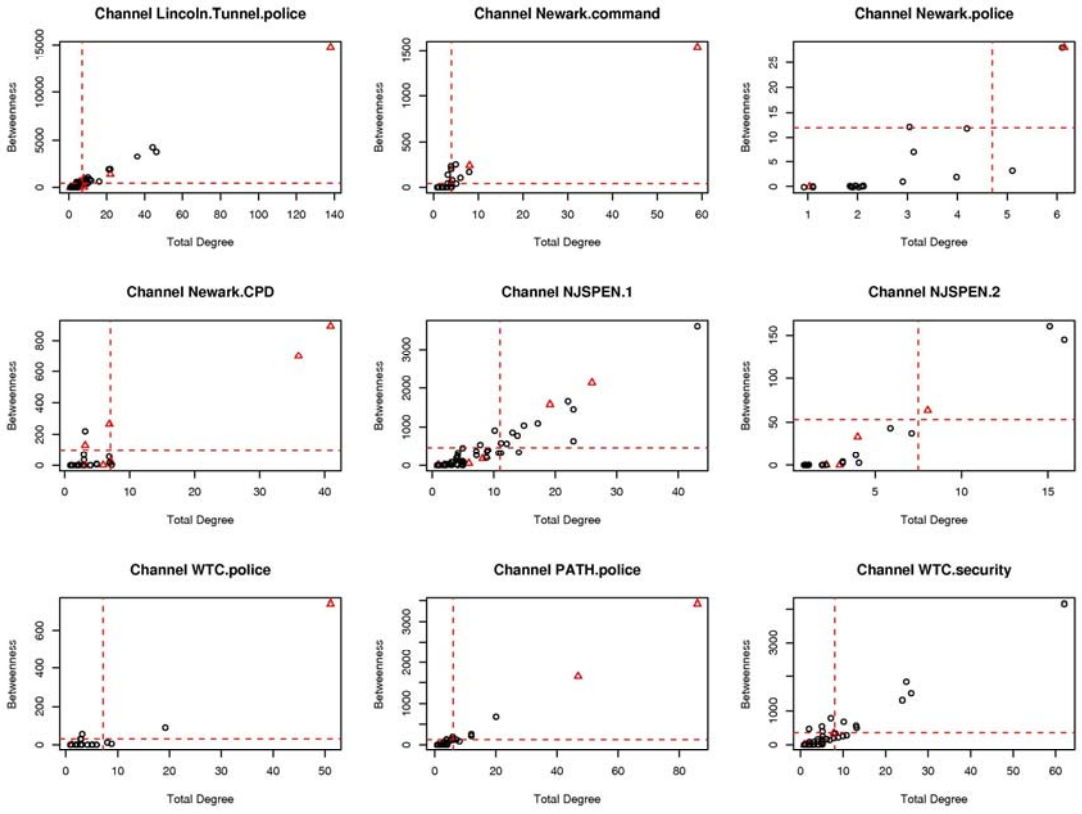
Figure 2: Sociograms for WTC Radio Communications, Non-Specialist Responders



With this in mind, we proceed to examine the joint distributions of betweenness and degree for the WTC communication networks. These are shown for the specialist responder networks in Figure 3, with distributions for non-specialist responder networks given in Figure 4. To assist in identifying coordinative positions, 90 percent quantile lines have been superimposed for both measures; thus, the upper right quadrant of each plot can be interpreted as containing positions that effectively serve as coordinators for the corresponding network. (While the 90 percent threshold is somewhat arbitrary—chosen based on an examination of the underlying distributions—the results shown here are robust to reasonable alternatives.) As both figures suggest, degree and betweenness are very highly correlated for these networks ($Md = 0.95$, $IQR = 0.053$). This implies that, in these networks, responders with large numbers of partners also mediate ties between

numerous alters, and vice versa. We can thus reasonably speak of agents' overall extent of coordination within the communication system without distinguishing between degree and betweenness per se.

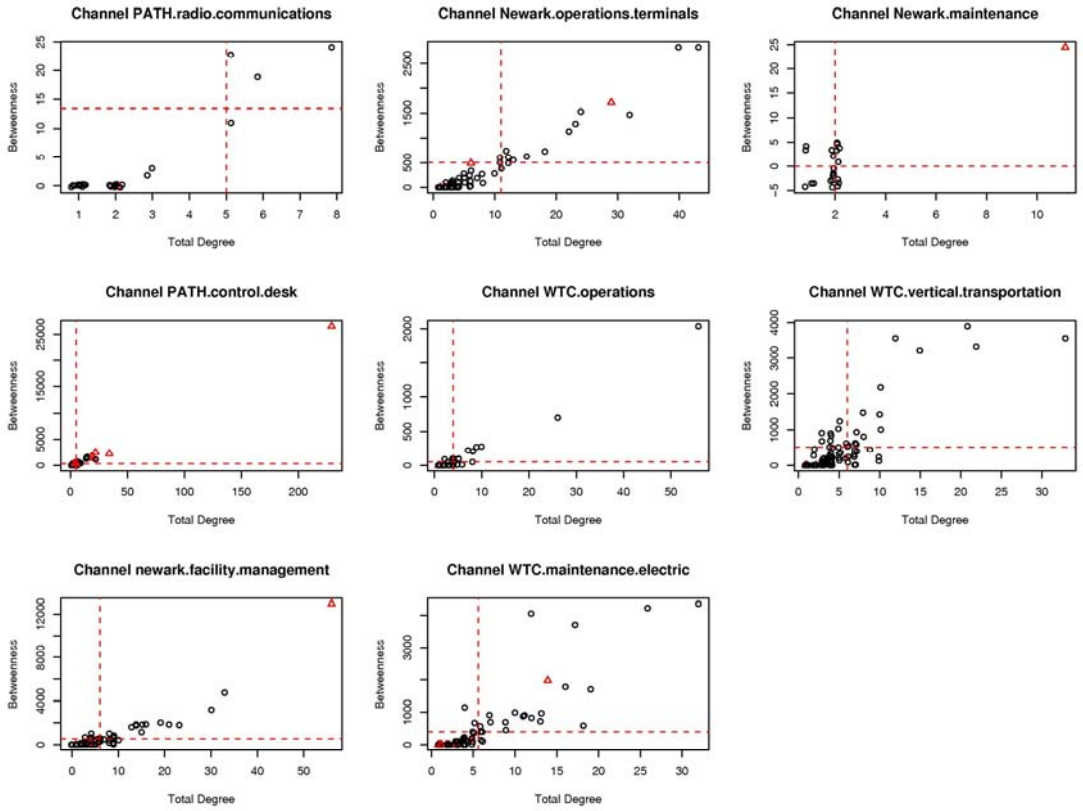
Figure 3: Combined Centrality Scores by Role Type, Specialist Responders



In addition to showing the degree/betweenness relationship for each network, Figures 3 and 4 allow us to identify differential occupancy of coordinative positions by responders with or without institutionalized coordination roles. Specifically, responders with such roles are designated in each figure via light-colored triangular markers, as opposed to the darker circular markers used for undifferentiated responders. Using the joint 90 percent threshold as the practical truncation point for coordinator status, it is plain that both institutionalized and emergent coordinators are found across the WTC communication networks. Although networks can be found for which each type dominates, the most common pattern appears to be a mixture of coordinators with and without institutionalized roles; this is true for both specialist and non-specialist responder networks. Nor does this result appear to depend upon the choice of a 90 percent threshold; as Figures 3 and 4 show, mixtures of institutionalized and emergent

coordinators can be found throughout the upper tails of most betweenness/degree distributions. It is thus immediately apparent that we must reject the simple hypotheses that coordination activities in the WTC were simply a matter of formal, institutionalized role performance, and that overwhelming differences in coordinator types were present for specialist versus non-specialist responders.

Figure 4: Combined Centrality Scores by Role Type, Non-Specialist Responders



Simple inspection, however, cannot establish the relative prevalence of coordinator types, nor assess whether minor but significant differences might exist between specialist and non-specialist responder networks. For this reason, we now turn to a more detailed analysis. Frequency statistics for observed coordinator roles by institutional and specialization status are shown in Table 2. Collapsing rates across responder type, we note immediately that a substantial majority (approximately 87 percent) of coordinators are emergent, while a minority (approximately 25 percent) of institutionalized agents are coordinators. This is clearly consistent with the notion that realized coordination roles during emergencies are not generally predetermined, and that most individuals occupying

these roles come to do so on the basis of situational factors. This is not the whole story, however. When we consider the odds of assuming a coordinative role, we find that the institutionalized agents are almost three times as likely to do so as agents without an equivalent status—24.7 percent vs. 8.5 percent; $\chi^2 = 26.73$, $df = 1$, $p < .00001$ (all χ^2 p-values include continuity correction where applicable). This apparent paradox is resolved by noting that institutionalized agents make up just under five percent of the population; thus institutionalization *does* greatly contribute to the chance that any given agent will take a coordinative role, but this effect is overwhelmed by the fact that there are many more potential emergent coordinators from which to select. Hypothesis H2 is thus supported, with the caveat that its practical import is substantially limited by base rate effects.

Table 2: Coordinator Role by Institutionalized Status, Specialist and Non-specialist Responders

	Specialist Responders		Non-specialist Responders	
	Coordinators	Non-coordinators	Coordinators	Non-coordinators
Institutionalized	12	37	12	36
Non-institutionalized	52	680	109	1044

Turning to a slightly different question, H3 predicts differences in the relative tendency of coordinative roles to be institutionalized versus emergent by specialization. As we have already seen, institutionalized coordinators are relatively rare—accounting for only about 13 percent of coordinative roles throughout the entire WTC system. Breaking the results down by specialization, we find that 18.8 percent of coordinative roles are institutionalized within specialist networks versus 9.9 percent within non-specialist networks. At first blush, this seems to support hypothesis H3; however, the aggregate difference is not significant ($\chi^2 = 2.16$, $df = 1$, $p = 0.14$). Due to the relatively small numbers involved, it is reasonable to consider whether the results are robust to group-level heterogeneity. Permutation tests of differences in institutionalized versus emergent coordination rates by group are inconclusive, leading to p-values of 0.056 and 0.042 for median and mean differences, respectively (both one-tailed tests). Taken together, these tests indicate that while the data is suggestive of the differences predicted in H3, the differences are not substantially in excess of what would be expected by chance. H3 is hence unsupported, although the data are somewhat equivocal on the matter.

Given the above, it is also natural to ask whether institutionalized status affects the recruitment of specialist and nonspecialist responders into coordinative roles in the same overall way. To test the hypothesis of a possible moderating effect of specialization on the institutionalized/emergent coordinator odds ratio (H4), we follow the standard procedure of comparing the fit for a loglinear model with all one and two-way marginals to the fit for the saturated model for Table 2 (Bishop et al. 1975). The one and two-way effects model fits well (LR vs. saturated model $\chi^2 = 0.32$, $df = 1$, $p = 0.57$), providing no evidence of a three-way interaction between specialist status and the institutionalization-coordinator relationship. (Similar results were also obtained from an equivalent Monte Carlo test ($p = 0.37$), and by a group-level permutation test controlling for unobserved heterogeneity ($p = 0.185$).) Thus, contrary to H4, we find no difference in the effect of institutionalization for the two groups. There is one caveat to this result, however: agents with institutionalized status are 1.5 times as common in specialist responder networks as they are in non-specialist networks ($\chi^2 = 4.79$, $df = 1$, $p = 0.029$). Somewhat more institutionalized coordinators are likely to appear in specialist networks, in relative terms, simply due to a higher incidence of agents with institutionalized communication roles. The impact of specialization which was hinted at in the analysis of H3 may thus lie more in the mix of responders at the scene than in the tendency of individuals to take on coordinative roles.

Conclusion and Implications

The purpose of this study was to shed some light on the problem of coordination in communication during disasters, by investigating whether institutionalized coordinators (i.e., people whose role in the organization is specifically to coordinate communication) are more central in emergency phase communication networks, and whether specialist and non-specialist responder organizations have different responses to the challenges posed by a disaster environment to their communication structure.

Our main findings may be summarized as follows. First, respondent communication networks within the WTC disaster—regardless of source or responder type—are dominated by a relatively small number of agents acting as coordinators, who are linked to (and mediate the connections among) many communication partners. While both institutionalized and emergent coordinators are found across the WTC networks, the vast majority of coordinators appear to be emergent (in the sense of having no institutionalized coordinative role). That said, agents with institutionalized coordinative roles are much far more likely to wind up as *de facto* coordinators than agents without such roles; prior institutional arrangements do affect the response process. Somewhat

surprisingly, networks of specialist responders seem to display the same chance of coordination given institutionalization. Because these networks do tend to contain more agents with institutionalized coordinative roles, however, they end up containing a somewhat larger number of institutionalized coordinators. Nevertheless, in the end this effect is small compared to the overall prevalence of emergent coordination in these networks.

The unexpected lack of strong differentiation between specialist and nonspecialist responder networks suggests that the same processes may be governing emergent coordination in each, and that the factors that shape these processes are not ones that vary strongly across organizational type. It is tempting to propose that these factors may be due to the crowded, confused nature of the WTC site, but this is not consistent with the fact that many of the networks analyzed here involved communication among those at remote locations. As we do not currently have baseline communication data for these organizational populations, we cannot say for certain that these effects do not reflect day to day similarity, but this would seem to run counter to prior studies of such organizations. What can be said is that the substantial role played by emergent coordination at the WTC for responders of all types underscores the importance of identifying the processes by which coordination emerges during the early phases of disaster. Mechanisms such as preferential attachment (e.g., a tendency to call those who have recently been heard on-air leading to a positive feedback loop of participation) or differential opportunity (e.g., the delegation of coordination to those agents who happen to reside in safer locations) are among the many which would seem to be worthy targets of investigation.

By obtaining a deeper understanding of the processes by which coordinators emerge during times of crisis, organizations of all types can be better prepared to develop an effective response to extreme events. While it is important to remember that this is a single case, some tentative policy implications may be identified for the allocation of resources within crisis settings. Based on the results presented above, we offer the following three propositions.

First, individual patterns of communication may vary greatly in a crisis—some responders will generate substantially more communication volume than others, and may have to converse with a much larger number of partners. Given this, robust communication systems must be accommodating of user heterogeneity, and should permit usage extremes. Bandwidth caps and other triage mechanisms should be evaluated carefully, to ensure that they will not impair the ability of key personnel to coordinate response activities.

Second, perhaps surprisingly, usage patterns for non-specialist response organizations may look much like those of specialist response organizations during periods of crisis. As

such, designers of robust communication systems for large facilities (such as the WTC) should take into account many of the same factors as designers of communication systems for emergency response organizations. In particular, it should be borne in mind that the true first responders to disasters in urban settings will often be building personnel or others (trained or not) who happen to be at the initial impact site.

Third, although communication patterns vary greatly by responder, it is often difficult to predict who will wind up being central in a crisis; thus, systems that restrict communication system usage based on formal institutional roles may inadvertently deny critical resources to those who need them the most. Systems should ideally be flexible to changing needs, and should allow for rapid reconfiguration during a crisis.

Disaster researchers have suggested that there are two opposing models of emergency management. The first is a strict, rigid, and centralized command and control model, whose popularity stems from the civil defense origins of emergency management and the rational orientation of classic management theory (Drabek and McEntire 2002). Some of the assumptions on which this perspective is based include the notions that information outside of official channels is lacking or inaccurate, emergency personnel are likely to leave their posts if not strictly controlled, standard operating procedures will function normally during disasters, and members of the general public are generally passive and/or irrational. These assumptions produce, in turn, certain guidelines for disaster response operations, most notably the need for paramilitary leadership, concentration of decision-making, and top-down communications (Drabek and McEntire 2002, p. 202-203). In the aftermath of the September 11 attacks—and especially after Hurricane Katrina (Tierney 2003b; Tierney et al. 2006)—this perspective has received considerable institutional support within the United States, becoming the main framework for disaster operations at the federal level as enshrined in NIMS (Buck et al. 2006). The second perspective questions the value of this top-down, bureaucratic model for disaster response, positing that response operations should be decentralized, flexible, and based on local cooperation. In this approach, the focus is placed on learning, innovation, and an acknowledgment of the fact that there is more than one way to organize, with emergent phenomena being viewed as a resource rather than a liability (Drabek and McEntire 2002). Consistent with this second perspective, lack of flexibility was one of the main failures identified by the Select Bipartisan Committee to Investigate the Preparation for and Response to Hurricane Katrina (to investigate the preparation for and response to Hurricane Katrina 2006). They note that “Response plans at all levels of government lacked flexibility and adaptability. Inflexible procedures often delayed the response. Officials at all levels seemed to be waiting for the disaster that fit their plans, rather than planning and building scalable capacities to meet whatever Mother Nature threw at them” (p.2-3).

We believe that our results, which demonstrate the prevalence of emergent coordination within the WTC response, suggest significant difficulties for response strategies that depend upon pre-event identification of "key players" in the response process. Although prior institutional structure has some influence on who ends up in coordinator roles, the overwhelming majority of coordinators in the WTC case do not appear to have special institutional status—likewise, most of those whose status might suggest coordinative responsibilities did not in fact become highly central actors. Insofar as this case is typical, it is not obvious that planners can effectively predict who will occupy critical coordination roles during the first hours of a disaster, nor that attempts to channel communication along institutionally prescribed lines will be efficacious. (The lack of substantial differences between specialist and nonspecialist networks in the WTC case makes the latter particularly questionable.) While these observations do not imply that command and control approaches *cannot* be made to perform well, they do add to the growing body of research that identifies severe obstacles to the success of strategies which are insufficiently flexible. In particular, the analyses presented here suggest that, when devising disaster response plans, it may be inadvisable to limit communication coordination roles and resources to a pre-specified group of individuals. Response plans that require advance knowledge about which persons will fulfill the role of communication "hubs" may not provide enough flexibility top prove useful in the midst of the rapidly changing environment that is characteristic of most disasters.

Notes

1 Apart from the life cycle approach outlined above, another widely used concept regarding the classification of disaster periods is that of the four phases of disaster activity: mitigation, preparedness, response, and recovery. In this framework, the actions captured by our study would fall into the response phase.

2 Some evidence suggests (see, e.g. Baron et al. 1992) that complex, non-decomposable information tasks may favor decentralized structures; however, achieving problem segmentation (and hence decomposability) is itself a mark of effective coordination systems (Perrow 1970).

3 Note that we here consider both incoming and outgoing ties (total degree), unless otherwise indicated.

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